ELEVATED VACUUM: RESIDUAL LIMB SKIN’S EXPOSURE TO AIR PRESSURE
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INTRODUCTION
Elevated vacuum provides an active evacuation of the air between the prosthetic liner and prosthetic socket. There is minimal knowledge regarding the resulting effect on residual limb skin. Further understanding of the conditions experienced by the amputee’s residual limb skin is advantageous to the knowledge and advancement of elevated vacuum.

Previous research has investigated the air pressure between the prosthetic liner and residual limb skin during swing phase focusing only on the distal location and vacuum pressure at 20 inHg (Beil, 2002). The purpose of this research was to further investigate the air pressure conditions experienced by the residual limb skin under different vacuum pressure levels, at different locations and different phases of gait.

METHOD
Subject: A K3 transtibial amputee utilizing an elevated vacuum prosthesis participated in the study. The prosthesis incorporated a 7% reduced socket with a zero ply fit.

Apparatus: Teflon tubing (0.51 mm diameter) connected to pressure sensors contained in a data acquisition box were used to measure the air pressure between the liner and the skin. Each sensor was calibrated using a NIST vacuum gage and real time data was collected at 50 Hz.

Procedures: The tubing was positioned at four locations (distal, medial side of the tibia, lateral side of the tibia, and proximally medial side of the tibia). The subject ambulated in place while air pressure measurements were taken under three pressure conditions (0 inHg, -14 inHg, and -20 inHg) and under two socket conditions (well fitting and poor fitting). For the poor fitting socket condition the distal liner thickness was reduced by 6mm.

Data Analysis: Peak air pressures were determined over an interval of four consecutive steps for both stance and swing phases.

RESULTS
For stance phase, positive pressures saturated out at approximately 3 inHg. For swing phase, negative air pressures were generated and varied according to test condition. A summary of the air pressures for swing at the distal and proximal sensor is located in Table 1.

Table 1: Air pressure between the liner and skin during swing phase

<table>
<thead>
<tr>
<th>Pressure Testing Conditions</th>
<th>Swing Phase - Peak Pressures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Well Fitting Socket</td>
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<tr>
<td></td>
<td>Distal Sensor (inHg)</td>
</tr>
<tr>
<td>0 inHg</td>
<td>-2</td>
</tr>
<tr>
<td>-14 inHg</td>
<td>-4</td>
</tr>
<tr>
<td>-20 inHg</td>
<td>-6.8</td>
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</tbody>
</table>

DISCUSSION
Between the liner and the skin, air pressure fluctuated between positive and negative pressure during ambulation. Peak air pressures were correlated with the different pressure testing conditions and locations. At higher vacuum pressure settings, the liner is drawn closer to the socket, producing greater negative pressures between the skin and the liner, especially at the distal end. The poor fitting socket exhibited greater negative pressures compared to the well fitting socket. The controlled conditions conducted in this study did not result in a blister formation. But if the poor fitting socket was in the form of a localized void, the potential for a blister to form maybe present (Sehgal, 2006). The air pressures from a previous study, which tested a 4% reduced socket, were comparable to the pressures reported for the poor fitting socket in this study. The previous study only measured the distal end at the highest vacuum setting.

CONCLUSION
The presence of negative pressure on the skin assists the flow of fluid into the residual limb. The study results indicate that the level of vacuum and the socket fit exhibit a pressure gradient on the amputee’s residual limb skin.

CLINICAL APPLICATIONS
The research expands the understanding of elevated vacuum’s effect on residual limb skin at different pressure settings and locations. The study also demonstrated the influence of socket fit and the potential significance of a poor fitting socket.

REFERENCES